SENTINEL 2

Mission Performance Centre

The power of innovation

esa

European Commission

CURRENT VALIDATION STATUS OF SEN2COR

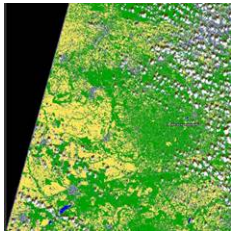
S2VT01, FRASCATI,

28/11/2016-29/11/2016

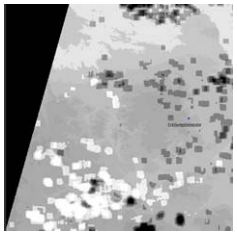
CS ACRI ST ARGANS elecnor deimos gmv AIRBUS DEFENCE & SPACE ThalesAlenia Space IGN ONERA TELESPAZIO a LEONARDO and THALES company DLR

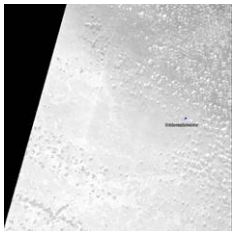
OVERVIEW

- Sen2cor Processor
- Validation dataset
- Validation of Cloud Screening and Scene Classification (CSC)

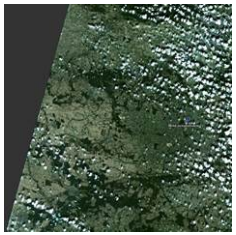


- Validation of AOT & WV



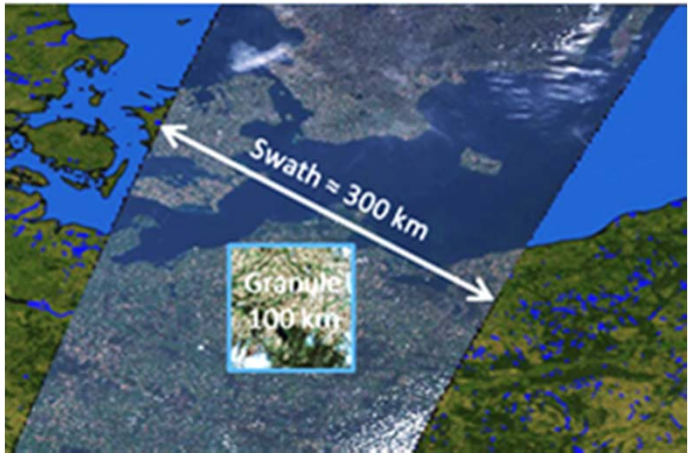


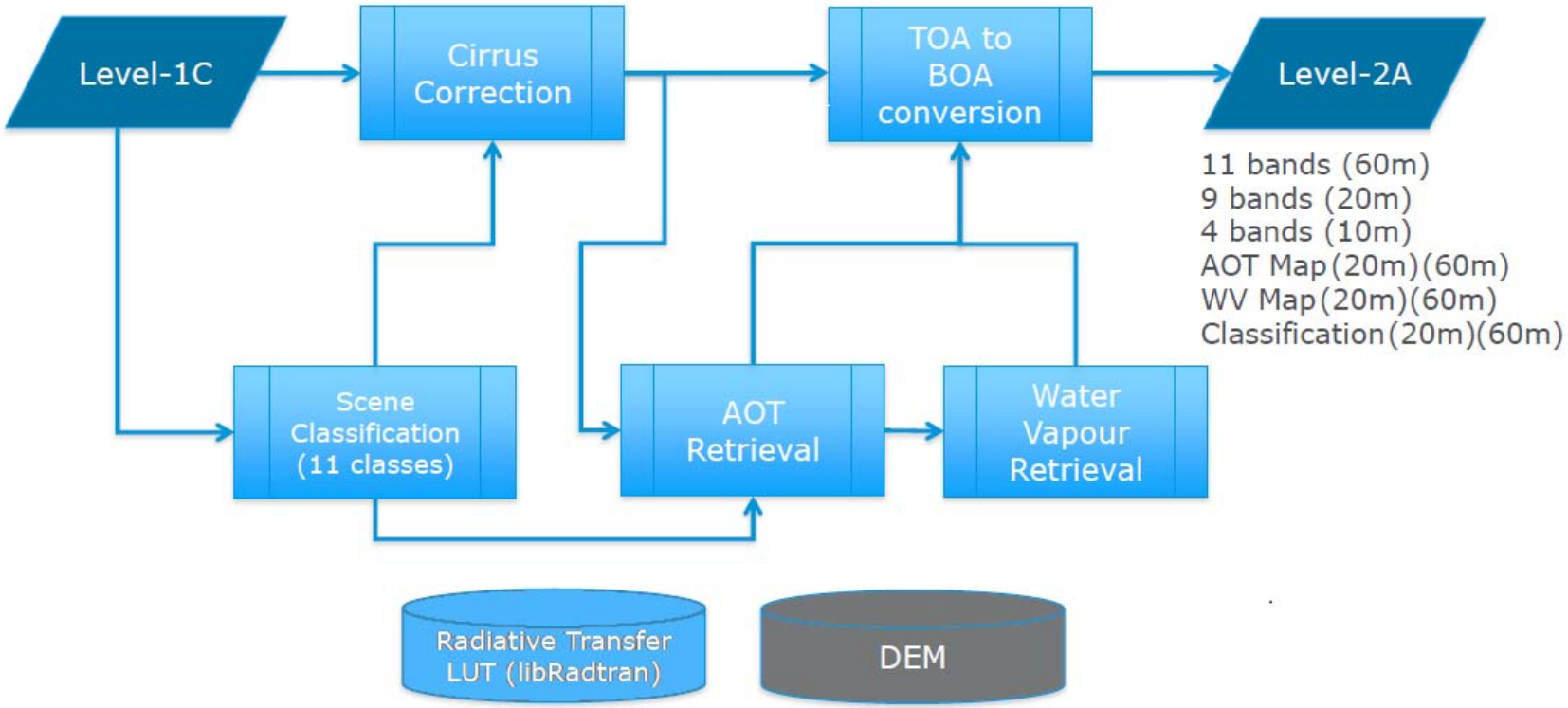
- Validation of Surface reflectance (BOA)



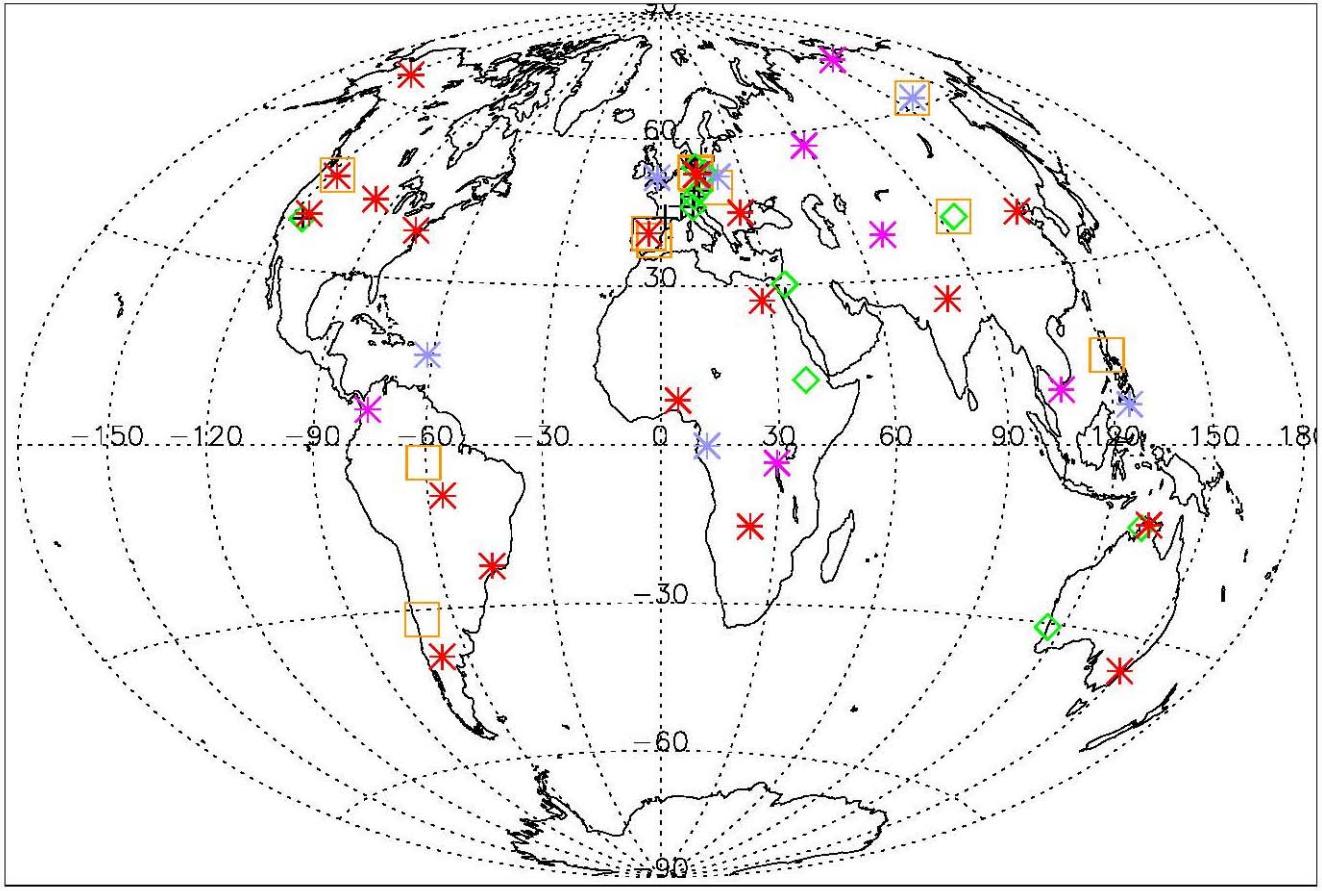
SEN2COR OVERVIEW

- Python application, Command line tool, also available from S2 toolbox
- **Single-Mission** tool for Sentinel-2 mission
- Processing on orthorectified L1C granule for a **single-time** image
- Atmospheric Correction over **land** surface
- Dense dark vegetation (**DDV**) pixels required





VALIDATION DATA SET



The locations were selected according to 8 latitude regions that will be covered by Sentinel-2 mission from North to South:

Polar (North),
Boreal,
Mid Latitude North,
Sub Tropical North,
Tropical,
Sub Tropical South,
Mid Latitude South,
Austral.

Orange squares: 11 test sites [100x100 km^2] for Cloud Screening and Scene Classification Validation

Asterisks: sunphotometer test sites [9x9 km^2] for validation of AOT, WV and BOA-products

Green diamonds: ad-hoc campaign sites for surface reflectance validation

METHOD

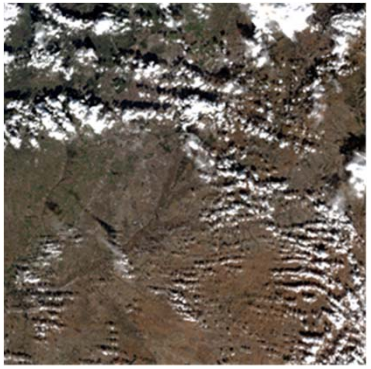
➔ Classes

Classification
NO_DATA
SATURATED_OR_DEFECTIVE
DARK_AREA_PIXELS
CLOUD_SHADOWS
VEGETATION
BARE_SOILS
WATER
CLOUD_LOW_PROBABILITY
CLOUD_MEDIUM_PROBABILITY
CLOUD_HIGH_PROBABILITY
THIN_CIRRUS
SNOW

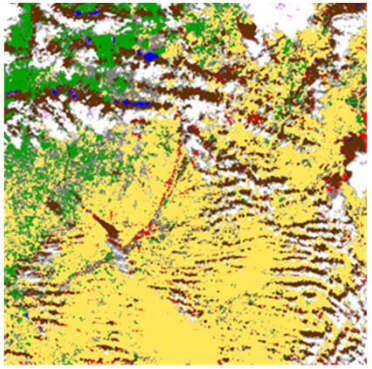
➔ Validation steps

- Run scene classification on full granule
- Stratified random sampling
- Pixel/area labelling by user (visual)
- Creation of reference image
- Confusion matrix,

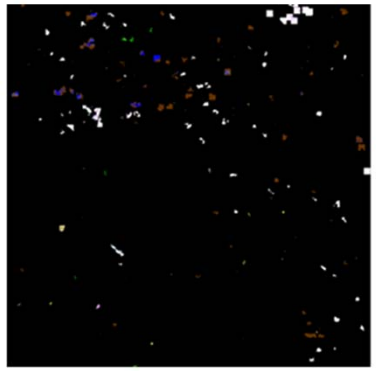
  precision, recall and overall accuracy



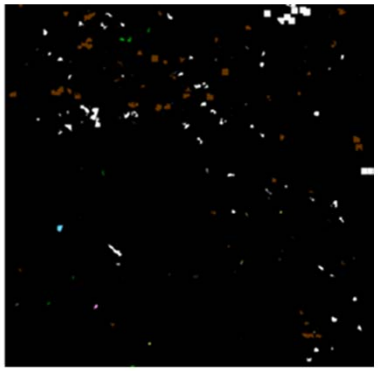
TOA RGB



Scene Classification



Ground truth classification image

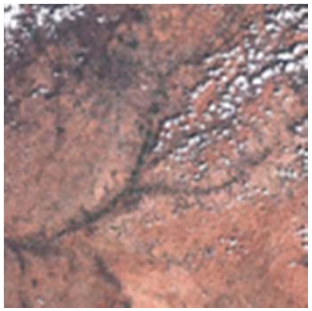


Sen2Cor classification image

CSC CONFUSION MATRIX

	Sen2cor class	Reference Class											Sum	Precision
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		
saturated_or_defective	(1)	**0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	none
dark_area_pixels	(2)	0%	**0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	none
clouds_shadows	(3)	0%	1,7%	**20,7%**	0,002%	0,035%	0,01%	0,8%	0,001%	0%	0%	0%	23,3%	89%
vegetation	(4)	0%	0,002%	0,001%	**2,9%**	1,6%	0%	0,005%	0%	0%	0%	0%	4,5%	65%
bare_soils	(5)	0%	0%	0%	0,04%	**3,7%**	0%	0,7%	0,4%	0,4%	0%	0%	5,2%	71%
water	(6)	0%	0,27%	0,03%	0,01%	0,02%	**7,9%**	0,02%	0%	0%	0%	0%	8,2%	96%
cloud_low_probability	(7)	0%	0%	0%	0,001%	0,04%	0%	**0,05%**	0,01%	0,01%	0,01%	0%	0,1%	40%
cloud_medium_probability	(8)	0%	0%	0%	0%	0,04%	0%	0,1%	**0,2%**	0,6%	0,02%	0%	1,0%	18%
cloud_high_probability	(9)	0%	0%	0%	0%	0,02%	0,01%	0,2%	2,7%	**52,7%**	0,9%	1,1%	57,7%	91%
thin_cirrus	(10)	0%	0%	0%	0%	0%	0%	0%	0%	0%	**0%**	0%	0%	none
snow	(11)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**0%**	0%	none
	Sum	0%	1,9%	20,7%	3,0%	5,4%	7,9%	1,9%	3,3%	53,8%	0,9%	1,1%	100%	

- Overall accuracy: 88 %
- Water (6) and cloud, high probability (9): exhibit similar high precision
- clouds_shadows (3): high precision for this example
- Vegetation (4) and bare soils (5): little lower precision
- Cloud low and medium probability (7,8): remarkable lower precision



Granule: T30TVK
Date: 18.08.2015
Region: Spain, Madrid area

OVERALL ACCURACY (OA)

SENTINEL 2

➔ Mean Overall Accuracy (OA):

› Number of correctly classified pixels of all classes relative to the total number of pixels

scene	Overall Accuracy
A	76,0%
B	77,5%
C	82,5%
D	84,0%
E	68,1%
F	88,1%
avg.	**79,6%**
std.	6,5%

➔ Influence of user:

Scene	user	OA	Total pixels
B	1	77,5%	267152
	2	86,8%	51273
	3	72,9%	279993
	4	75,0%	279993
	avg.	78,1%	271460,2
	std.	6,13%	
C	1	82,5%	216957
	2	77,2%	191627
	3	87,0%	42676
	avg.	82,2%	150420
	std.	4,91%	

➔ **Mean overall accuracy for all examples: (80 ± 7) %**

➔ Results obtained by different users on the same product show the same variation as processing different products by the same user

VALIDATION OF AOT & WV

Validation steps (AOT & WV)

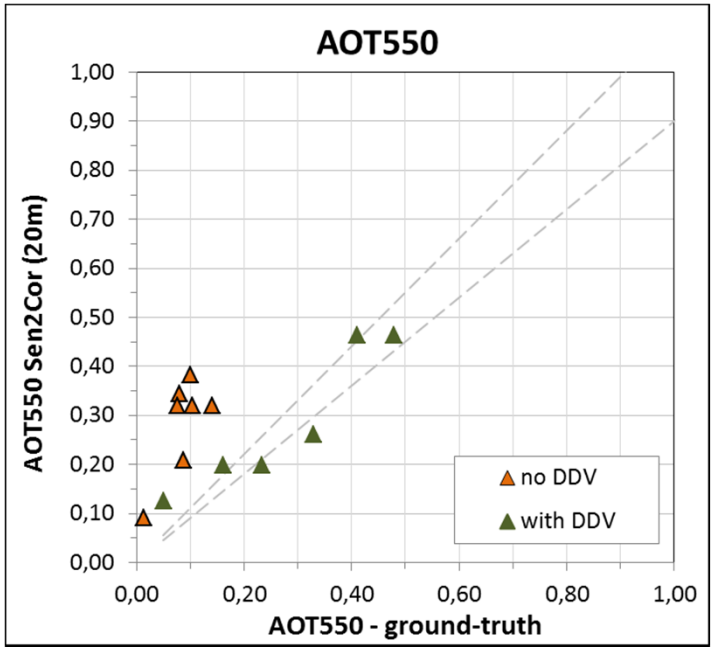
- Run Sen2Cor on full granule
- Extract 9×9 km² subset around sunphotometer
- Compute AOT statistics
- Compute Water Vapour (WV) statistics
- Download and process sunphotometer data as reference
- Compare Sen2Cor output with reference

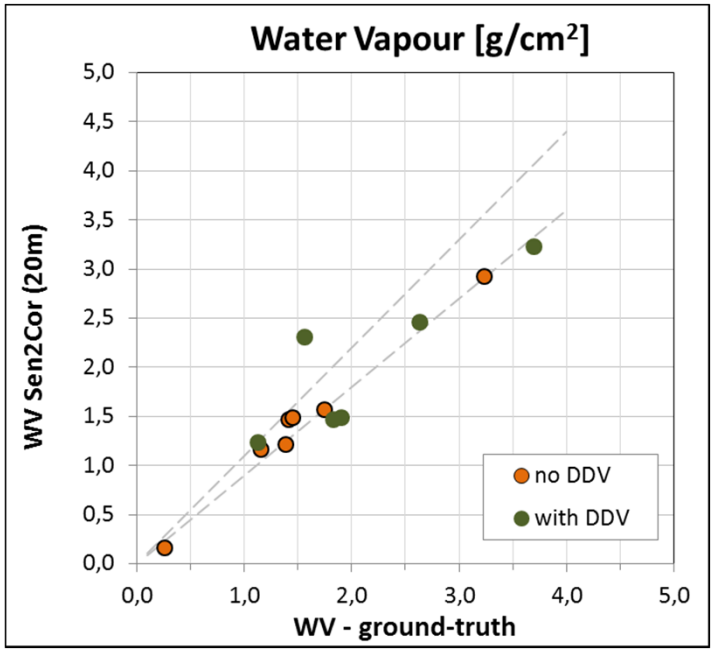
Results of AOT validation (samples up to 50% cloud cover):

- **mean AOT difference: 0.05** with DDV-pixels present.
  Maximum difference: 0.075
- Aerosol estimation fails, if no DDV-pixels in the image
- Fallback solution in preparation: Use AOT from ECMWF

Results of WV validation (samples up to 50% cloud cover):

- **mean WV difference: 0.25** g/cm²
  Maximum difference: 0.75 g/cm²
- Less influence of missing DDV pixels



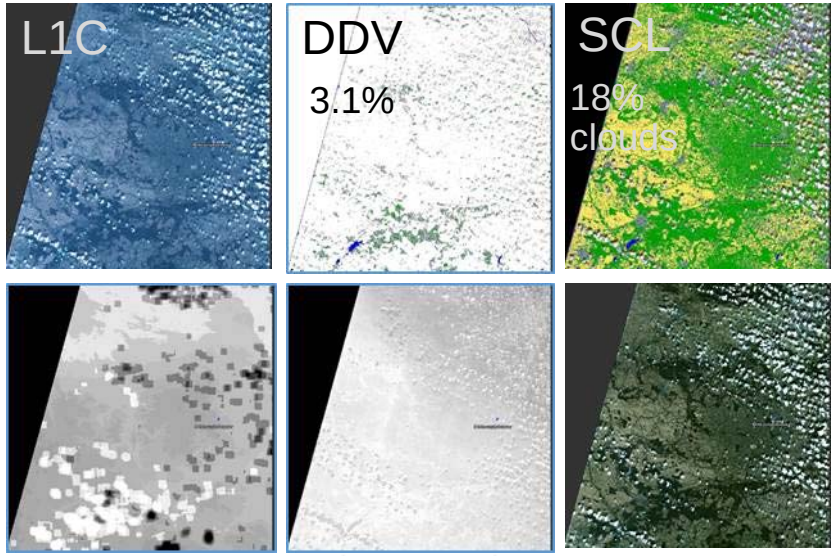


Acknowledgment: We thank the PI investigators and their staff for establishing and maintaining the AERONET sites used in this investigation.

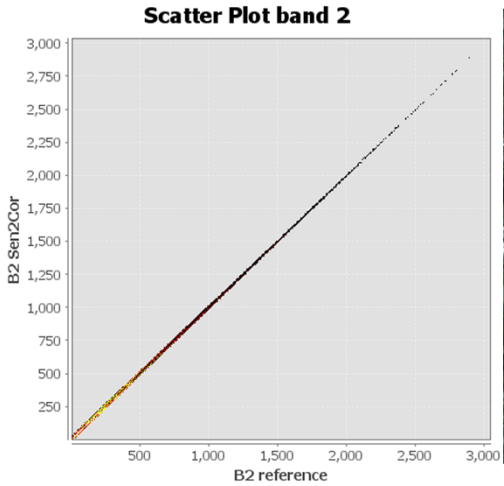
➔ Validation steps (BOA)

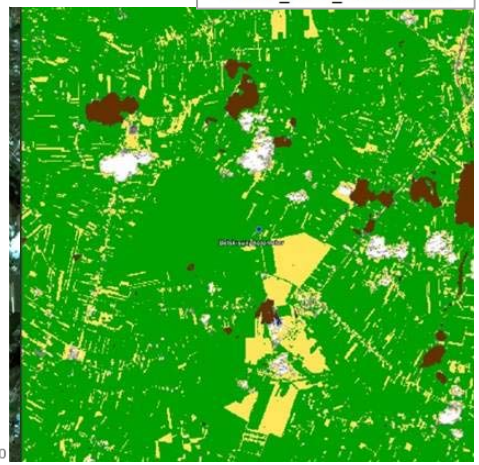
- › Run Sen2Cor on full granule
- › Run Sen2Cor with AOT = AERONET value (Generate reference dataset)
- › Extract spatial subset 9x9 km²
- › Compare Sen2Cor output with reference apply mask: [vegetation or soil (or water)]

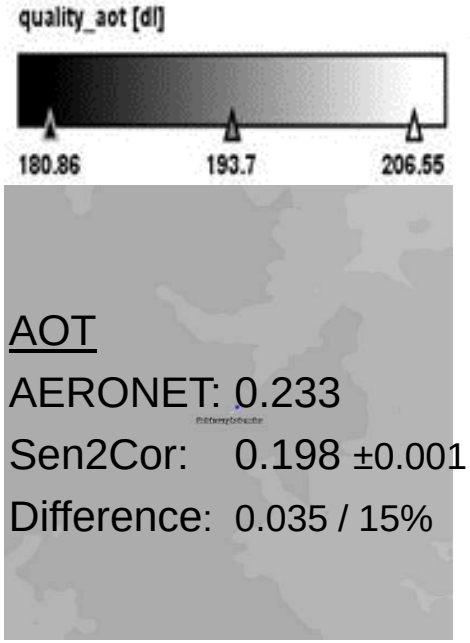
➔ **Full Granule;** Belsk test site / Poland; August 14, 2015; Sen2Cor 2.1.1

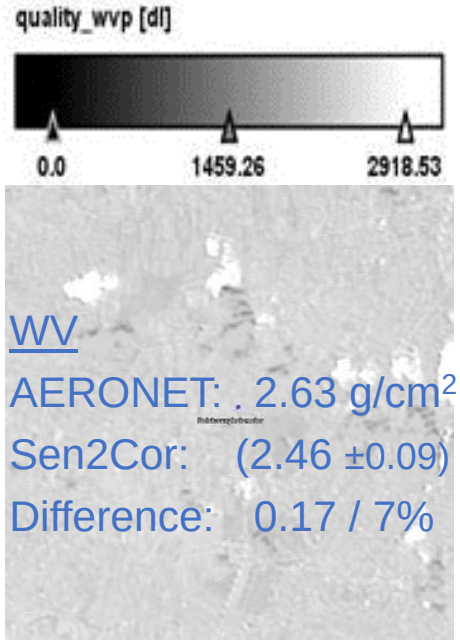


➔ Spatial subset



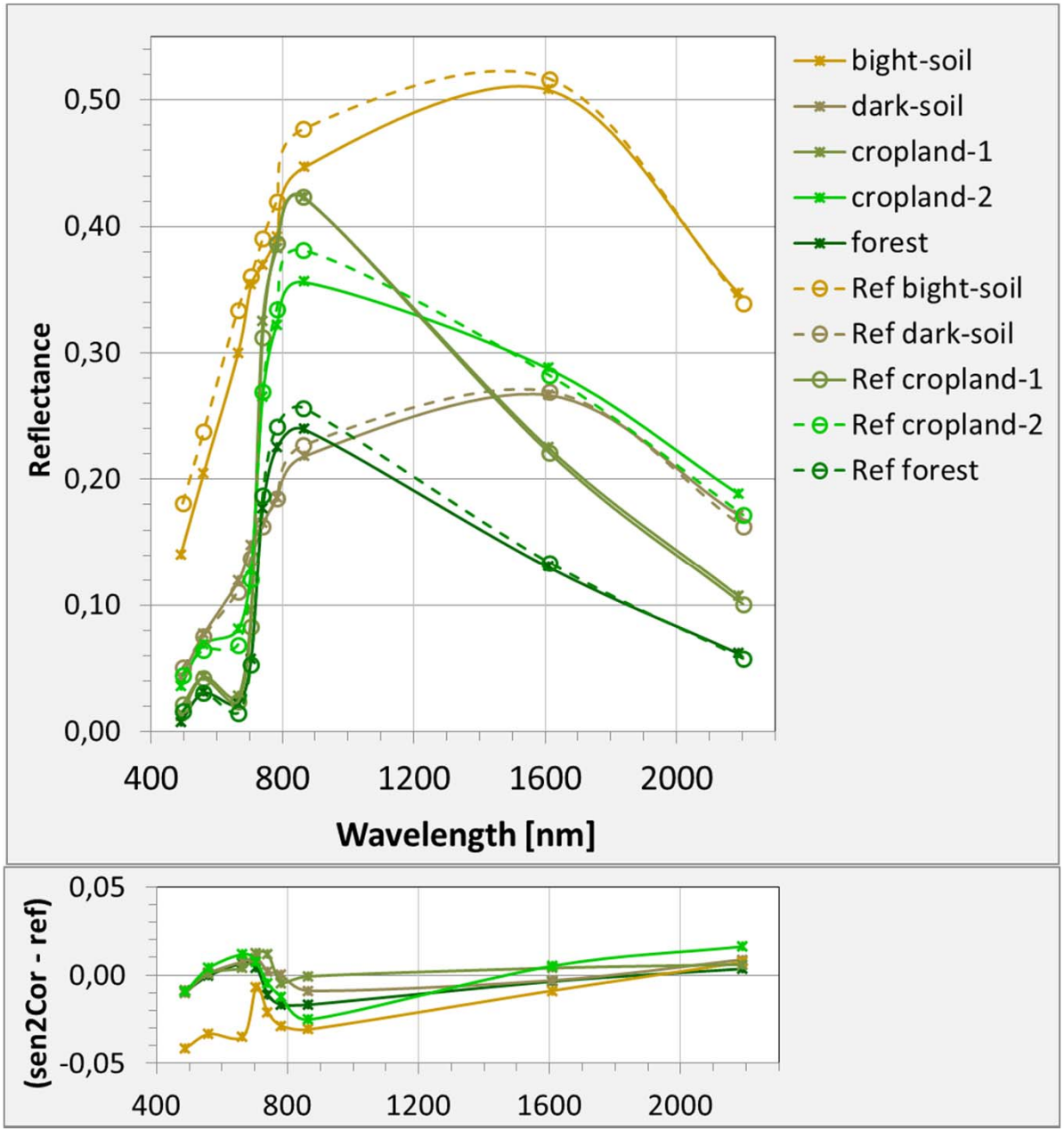






L1C-Product: S2A_OPER_PRD_MSIL1C_PDMC_20160226T220957_R036_V2015-08-14-T0942.SAFE
Granule: S2A_OPER_MSI_L1C_TL_EPA__20160224T113926_A000748_T34UDC_N02.01

VALIDATION OF SURFACE REFLECTANCE (BOA): RESULT



- Expected spectral dependency for reflectance spectra of different surface types
- Reflectance difference between Sen2Cor and reference up to 0.04
- NDVI-uncertainty up to 0.06

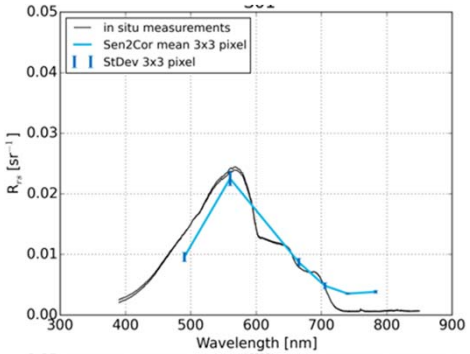
L1C-Product: S2A_OPER_PRD_MSIL1C_PDMC_20160226T220957_R036_V2015-08-14-T0942.SAFE
Granule: S2A_OPER_MSI_L1C_TL_EPA__20160224T113926_A000748_T34UDC_N02.01

Validation of Surface Reflectance (BOA): Lake Starnberg, August 13, 2015

Comparison with in-situ measured spectra above water surface

[Katja Doernhoefer, Uni Kiel]

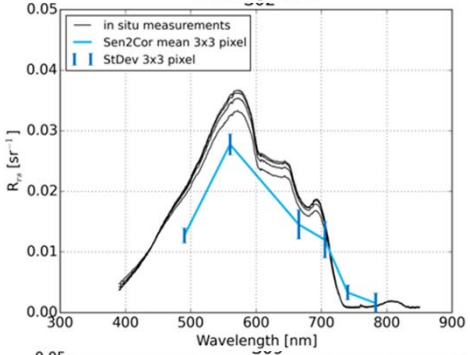
In situ vs. S2 spectrum



S01

Shallow water

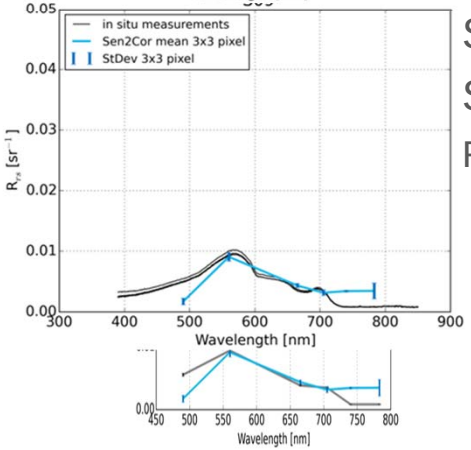
RMSE: 0.0027 sr^{-1}



S02

Shallow water

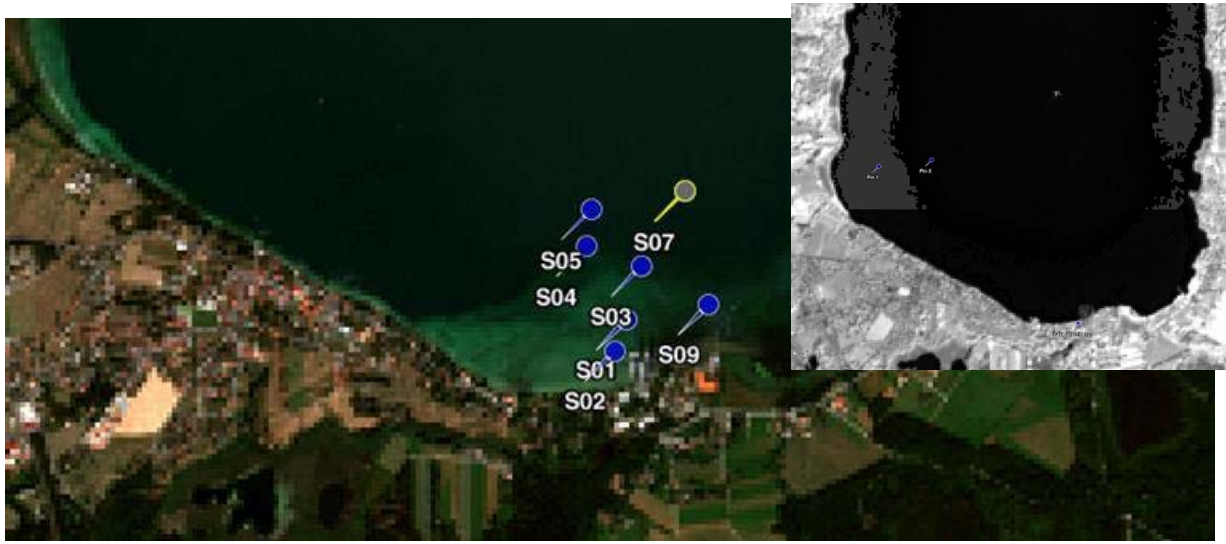
RMSE: 0.0051 sr^{-1}



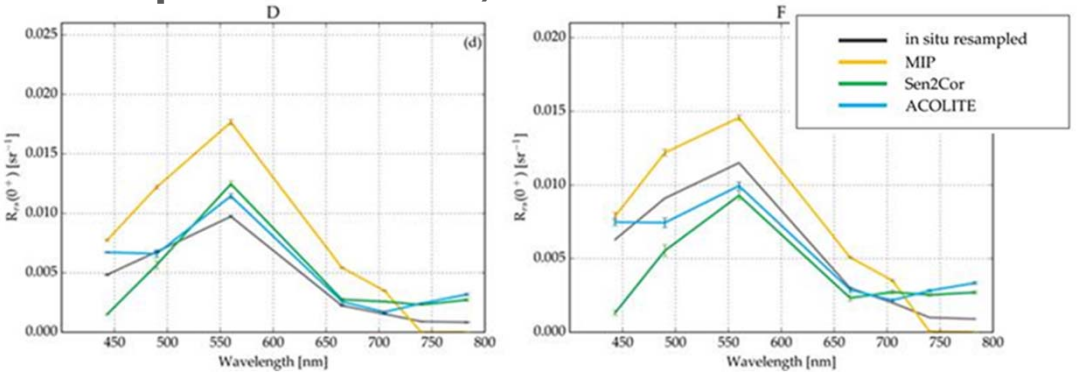
S09

Shallow water

RMSE: 0.0023 sr^{-1}



Comparison of MIP, ACOLITE & Sen2Cor



- Very good agreement in shape of spectra, small overcorrection by Sen2Cor in magnitude.
- Sen2Cor has potential for application over inland water
- **Negative reflectance values -> lost information about spectral shape**

Plots are copied from [Dörnhöfer, K.; Göritz, A.; Gege, P.; Pflug, B.; Oppelt, N.; Water constituents and water depth retrieval from Setinel-2A – a first evaluation in an oligotrophic lake, submitted to Remote Sensing]

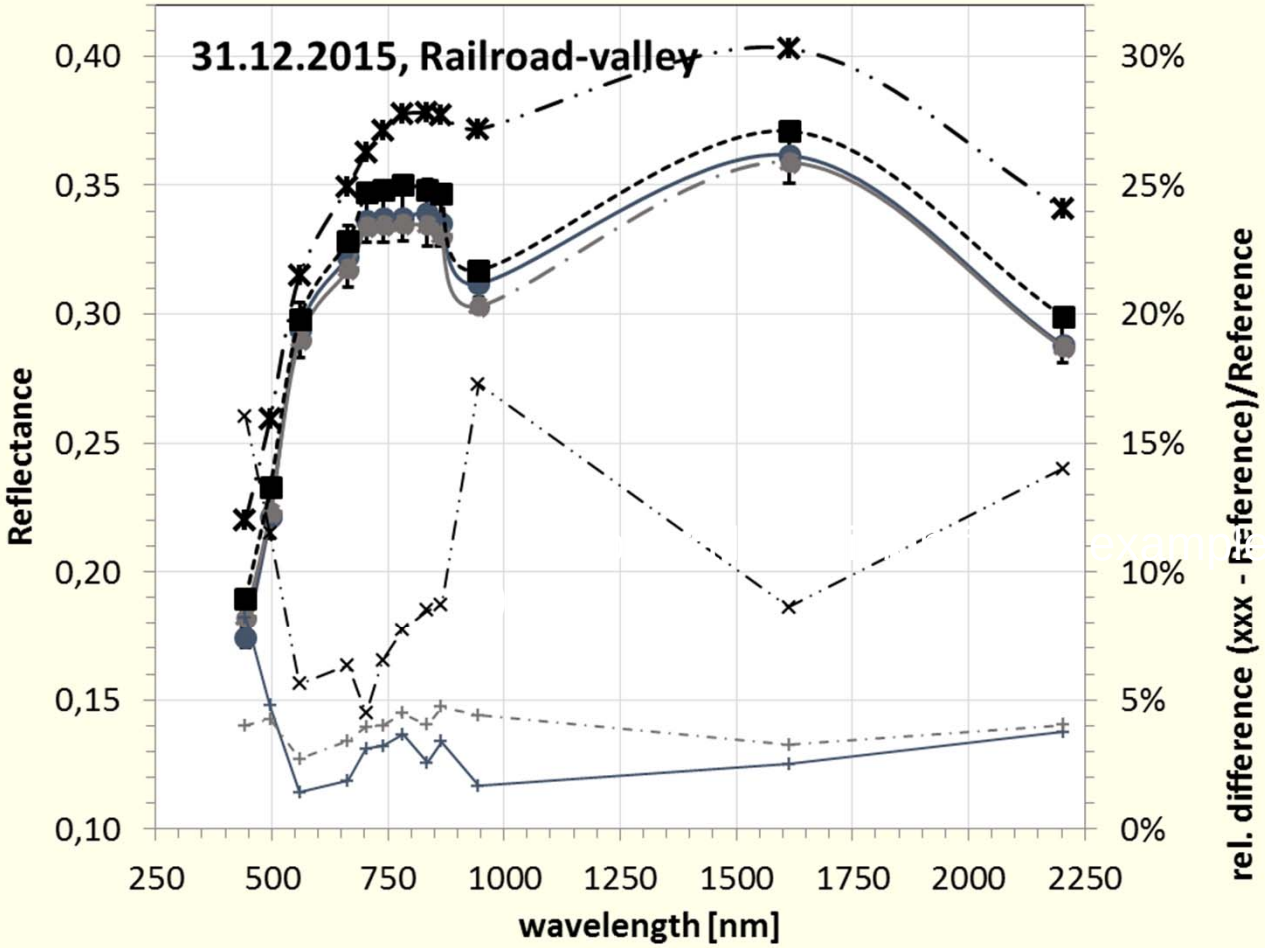
RRV DATASET 31.12.2015

- Test site without DDV → Aerosol estimation fails
- Should be used as an example investigating the benefit of using ECMWF-AOT instead of using Sen2Cor fallback VIS=40 km

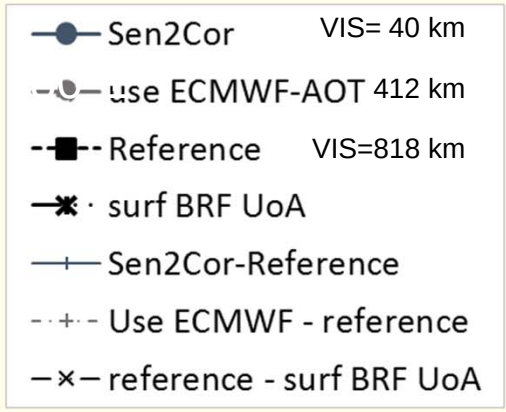
  (AOT=0.160 for RRV altitude)

L1C-Product: S2A_OPER_MTD_SAFL1C_PDMC_20160113T121102_R027_V20151231T184606_20151231T184606

VALIDATION OF SURFACE REFLECTANCE (BOA): RRV DATASET 31.12.2015



Input VIS Sen2Cor	Output AOT Sen2Cor	AOT ref
818 km Aeronet	0.04	0.013
412 km ECMWF	0.04	0.023
120 km LUT-Limit	0.06	
40 km default	0.09	



➔ Example shows no benefit of using ECMWF-AOT instead of using Sen2Cor fallback

➔ More investigation required

L1C-Product: S2A_OPER_MTD_SAFL1C_PDMC_20160113T121102_R027_V20151231T184606_20151231T184606

SEN2COR VALIDATION OUTCOME

➔Scene classification:

- Mean overall precision for Scene classification is (80 ± 7) %
- Highest precision for classes water and high probability cloud
- Precison for Classes vegetation, bare soils, dark_area_pixels and clouds_shadows is high for some images and low for other

➔AOT and WV retrieval:

- mean AOT difference: 0.05 if DDV pixels are existing in the granule.
- Aerosol estimation fails, if there are no DDV-pixels in the image.
- Processor evolution in preparation (using AOT form ECMWF)
- mean WV difference: 0.25 g/cm^2, less influenced by missing DDV pixels

➔BOA-reflectance retrieval:

- Reflectance difference between Sen2Cor and reference up to 0.04
- Campaigns: analysis to be continued

THANK YOU FOR YOUR ATTENTION!

Jérôme Louis
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Magdalena Main-Knorn
Jakub Bieniarz

Olivier Thepaut

Ferran Gascon

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